# Space News Update

## — February 23, 2018 —

## Contents

# 1. SpaceX Falcon 9 Sends Satellites into Space in Spectacular Predawn Launch

Just two weeks after launching a Tesla Roadster into space in the maiden flight of the Falcon Heavy rocket, SpaceX got back to business Thursday, launching a Falcon 9 carrying a $200 million Spanish radar imaging satellite and two experimental internet relay stations, pathfinders for SpaceX's proposed mega-network of orbital broadband beacons.

Running a day late because of high upper level winds, the 229-foot-tall rocket blasted off from Vandenberg Air Force Base, Calif., at 9:17 a.m. EST, streaking away to the south over the Pacific Ocean as it climbed toward an orbit around Earth's poles.

The rocket's first stage -- the ninth previously flown SpaceX booster to make a second flight -- powered the vehicle out of the thick lower atmosphere and then fell away two-and-a-half minutes after liftoff. No attempt was made to recover the used rocket, which fell back to Earth and crashed into the Pacific.

The company did, however, attempt to recover at least one of the nose cone panels that protected the satellite payload during the early moments of the flight. SpaceX has designed wing-like parafoils to guide the panels down to capture in a large net on a custom-designed ship -- Mr. Steven -- stationed down range from the launch site.

SpaceX founder Elon Musk confirmed parafoil deploy, but the descending nose cone panel did not make it to the capture net.

"Missed by a few hundred meters, but fairing landed intact in water," Musk tweeted. "Should be able catch it with slightly bigger chutes to slow down descent."

The company hopes to perfect the technology to routinely recover the $6 million components for refurbishment and reuse.

The single engine powering the second stage, meanwhile, fired for about six minutes and 20 seconds, putting putting Hisdesat's 1.5-ton PAZ -- "Peace" -- satellite into a 320-mile high orbit.

Using a sophisticated radar imaging system that can "see" Earth's surface through clouds, day or night, PAZ is designed to capture images showing features as small as 9.8 inches across, covering an area of nearly 116,000 square miles every day. The imagery will be provided to the Spanish government and its allies as well as commercial users.

"It's a very flexible mission," Miguel Angel García Primo, chief operating officer of Hisdesat, told Spaceflight

Now. "It's useful for a lot of applications, environmental, also for big infrastructure tracking and planning, maritime surveillance and government applications like monitoring and surveillance for any specific items that you'd like to follow."

PAZ will work in concert with two other synthetic aperture radar satellites already in orbit, TerraSAR-X and TanDEM-X, to provide very high resolution imagery and to shorten the time between overflights of high-priority targets.

While PAZ was the primary payload for Thursday's launch, much of the attention on the flight went to the secondary payloads, two SpaceX-developed orbital broadband prototypes known as Microsat-2a and Microsat-2b.

SpaceX did not mention the satellites in its press kit, but the company said in a Feb. 1 letter to the Federal Communications Commission that the 880-pound relay stations would be aboard. And on Wednesday, SpaceX founder Elon Musk tweeted the Falcon 9 "carries 2 SpaceX test satellites for global broadband. If successful, Starlink constellation will serve least served."

In an FCC application last year, SpaceX proposed a vast network -- Starlink -- of up to 4,425 small satellites, orbiting at altitudes between 689 and 823 miles, broadcasting internet content in high-speed Ku- and Ka-band frequencies. The company also has proposed launching more than 7,500 satellites in lower 210-mile-high orbits using different frequencies.

"These (satellites) are meant to gather data in advance of deploying and operating a satellite constellation that will provide Internet service," Tom Praderio, a SpaceX firmware engineer, said during the company's launch webcast.

"However, even if these satellites work as planned, we still have considerable technical work ahead of us to design and deploy a low Earth orbit satellite constellation," he said. "This system, if successful, would provide people in low to moderate population densities around the world with affordable high-speed Internet access, including many that have never had Internet access before."

The two microsats on board Thursday were released in the same orbit as PAZ. After checkout, both were to be maneuvered into 700-mile-high orbits. The satellites are equipped with phased array antennas and optical links for communications between spacecraft.

Nicknamed Tintin A and B, both spacecraft were communicating with ground stations and appeared to be healthy. Musk said in a tweet the satellites "will attempt to beam 'hello world' in about 22 hours when they pass near LA. Don't tell anyone, but the wifi password is 'martians.'"

FCC Chairman Ajit Pai said last week he supported SpaceX's proposed Starlink network, saying "to bridge America's digital divide, we'll have to use innovative technologies."

"Satellite technology can help reach Americans who live in rural or hard-to-serve places where fiber optic cables and cell towers do not reach," Pai said in a statement. "And it can offer more competition where terrestrial Internet access is already available.

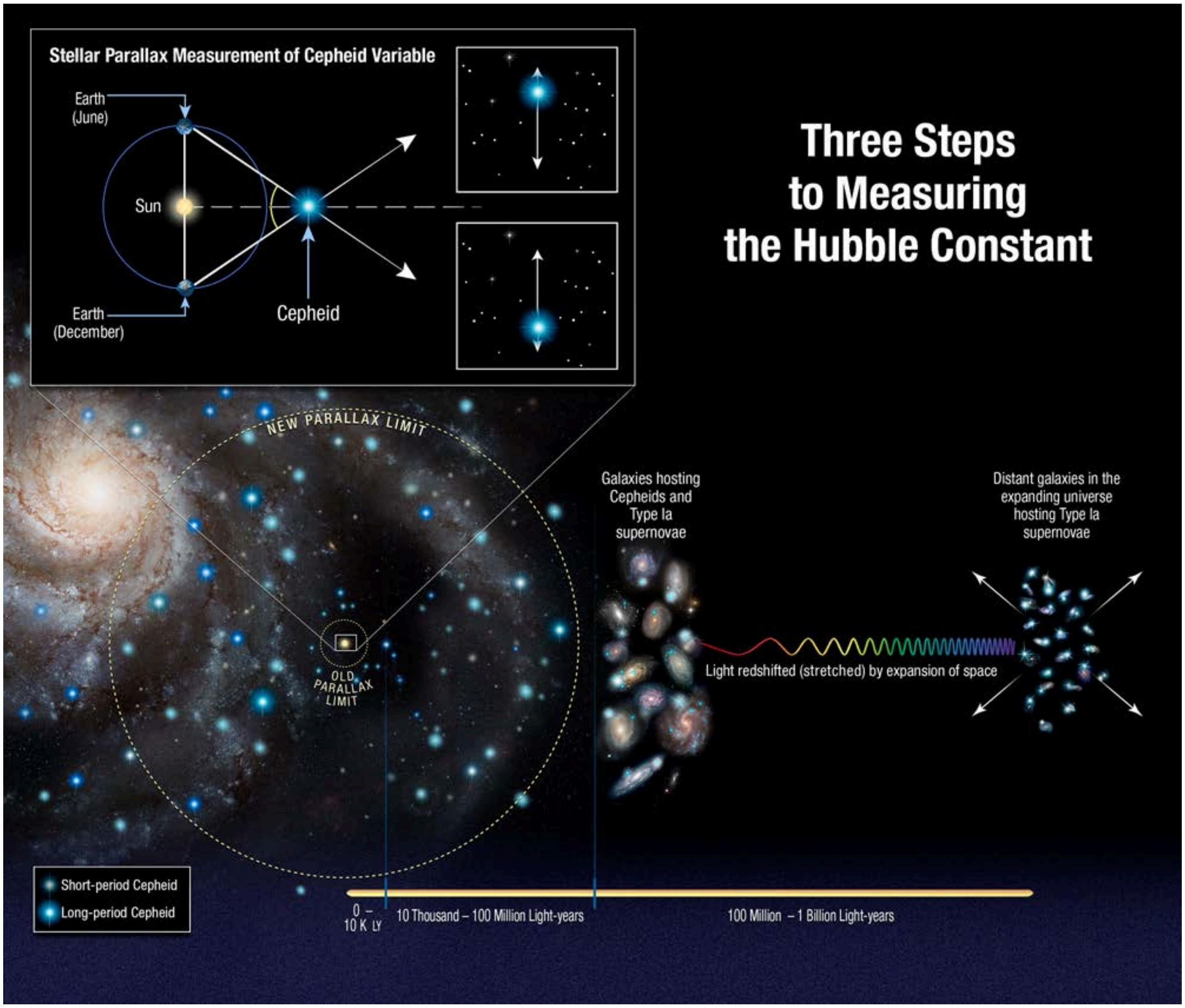
"I have asked my colleagues to join me in supporting this application and moving to unleash the power of satellite constellations to provide high-speed Internet to rural Americans. If adopted, it would be the first approval given to an American-based company to provide broadband services using a new generation of low-Earth orbit satellite technologies."

SpaceX faces stiff competition from OneWeb, a company that plans to launch more than 800 330-pound satellites. They will be built on a production line in an $85 million 100,000-square-foot factory near the Kennedy Space Center. OneWeb plans to launch its first spacecraft later this year from French Guiana atop a Soyuz rocket.

The FCC already approved OneWeb's proposal as well as another for a network being developed in Canada by Telesat.

Source: Spaceflight Now Return to Contents

## 2. Improved Hubble Yardstick Gives Fresh Evidence for New Physics in the Universe




Astronomers have used NASA's Hubble Space Telescope to make the most precise measurements of the expansion rate of the universe since it was first calculated nearly a century ago. Intriguingly, the results are forcing astronomers to consider that they may be seeing evidence of something unexpected at work in the universe.

That's because the latest Hubble finding confirms a nagging discrepancy showing the universe to be expanding faster now than was expected from its trajectory seen shortly after the big bang. Researchers suggest that there may be new physics to explain the inconsistency.

"The community is really grappling with understanding the meaning of this discrepancy," said lead researcher and Nobel Laureate Adam Riess of the Space Telescope Science Institute (STScI) and Johns Hopkins University, both in Baltimore, Maryland.

Riess's team, which includes Stefano Casertano, also of STScI and Johns Hopkins, has been using Hubble over the past six years to refine the measurements of the distances to galaxies, using their stars as milepost markers. Those measurements are used to calculate how fast the universe expands with time, a value known as the Hubble constant. The team's new study extends the number of stars analyzed to distances up to 10 times farther into space than previous Hubble results.

But Riess's value reinforces the disparity with the expected value derived from observations of the early universe's expansion, 378,000 years after the big bang — the violent event that created the universe roughly 13.8 billion years ago. Those measurements were made by the European Space Agency's Planck satellite, which maps the cosmic microwave background, a relic of the big bang. The difference between the two values is about 9 percent. The new Hubble measurements help reduce the chance that the discrepancy in the values is a coincidence to 1 in 5,000.

Planck's result predicted that the Hubble constant value should now be 67 kilometers per second per megaparsec (3.3 million light-years), and could be no higher than 69 kilometers per second per megaparsec. This means that for every 3.3 million light-years farther away a galaxy is from us, it is moving 67 kilometers per second faster. But Riess's team measured a value of 73 kilometers per second per megaparsec, indicating galaxies are moving at a faster rate than implied by observations of the early universe.

The Hubble data are so precise that astronomers cannot dismiss the gap between the two results as errors in any single measurement or method. "Both results have been tested multiple ways, so barring a series of unrelated mistakes," Riess explained, "it is increasingly likely that this is not a bug but a feature of the universe."

### Explaining a Vexing Discrepancy

Riess outlined a few possible explanations for the mismatch, all related to the 95 percent of the universe that is shrouded in darkness. One possibility is that dark energy, already known to be accelerating the cosmos, may be shoving galaxies away from each other with even greater — or growing — strength. This means that the acceleration itself might not have a constant value in the universe but changes over time in the universe. Riess shared a Nobel Prize for the 1998 discovery of the accelerating universe.

Another idea is that the universe contains a new subatomic particle that travels close to the speed of light. Such speedy particles are collectively called "dark radiation" and include previously-known particles like neutrinos, which are created in nuclear reactions and radioactive decays. Unlike a normal neutrino, which interacts by a subatomic force, this new particle would be affected only by gravity and is dubbed a "sterile neutrino."

Yet another attractive possibility is that dark matter (an invisible form of matter not made up of protons, neutrons, and electrons) interacts more strongly with normal matter or radiation than previously assumed.

Any of these scenarios would change the contents of the early universe, leading to inconsistencies in theoretical models. These inconsistencies would result in an incorrect value for the Hubble constant, inferred from observations of the young cosmos. This value would then be at odds with the number derived from the Hubble observations.

Riess and his colleagues don't have any answers yet to this vexing problem, but his team will continue to work on fine-tuning the universe's expansion rate. So far, Riess's team, called the Supernova H0 for the Equation of State (SH0ES), has decreased the uncertainty to 2.3 percent. Before Hubble was launched in 1990, estimates of the Hubble constant varied by a factor of two. One of Hubble's key goals was to help astronomers reduce the value of this uncertainty to within an error of only 10 percent. Since 2005, the group has been on a quest to refine the accuracy of the Hubble constant to a precision that allows for a better understanding of the universe's behavior.

### Building a Strong Distance Ladder

The team has been successful in refining the Hubble constant value by streamlining and strengthening the construction of the cosmic distance ladder, which the astronomers use to measure accurate distances to galaxies near to and far from Earth. The researchers have compared those distances with the expansion of space as measured by the stretching of light from receding galaxies. They then have used the apparent outward velocity of galaxies at each distance to calculate the Hubble constant.

But the Hubble constant's value is only as precise as the accuracy of the measurements. Astronomers cannot use a tape measure to gauge the distances between galaxies. Instead, they have selected special classes of stars and supernovae as cosmic yardsticks or milepost markers to precisely measure galactic distances.

Among the most reliable for shorter distances are Cepheid variables, pulsating stars that brighten and dim at rates that correspond to their intrinsic brightness. Their distances, therefore, can be inferred by comparing their intrinsic brightness with their apparent brightness as seen from Earth.

Astronomer Henrietta Leavitt was the first to recognize the utility of Cepheid variables to gauge distances in 1913. But the first step is to measure the distances to Cepheids independent of their brightness, using a basic tool of geometry called parallax. Parallax is the apparent shift of an object's position due to a change in an observer's point of view. This technique was invented by the ancient Greeks who used it to measure the distance from Earth to the Moon.

The latest Hubble result is based on measurements of the parallax of eight newly analyzed Cepheids in our Milky Way galaxy. These stars are about 10 times farther away than any studied previously, residing between 6,000 light-years and 12,000 light-years from Earth, making them more challenging to measure. They pulsate at longer intervals, just like the Cepheids observed by Hubble in distant galaxies containing another reliable yardstick, exploding stars called Type Ia supernovae. This type of supernova flares with uniform brightness and is brilliant enough to be seen from relatively farther away. Previous Hubble observations studied 10 faster-blinking Cepheids located 300 light-years to 1,600 light-years from Earth.

### Scanning the Stars

To measure parallax with Hubble, the team had to gauge the apparent tiny wobble of the Cepheids due to Earth's motion around the Sun. These wobbles are the size of just 1/100 of a single pixel on the telescope's camera, which is roughly the apparent size of a grain of sand seen 100 miles away.

Therefore, to ensure the accuracy of the measurements, the astronomers developed a clever method that was not envisioned when Hubble was launched. The researchers invented a scanning technique in which the telescope measured a star's position a thousand times a minute every six months for four years.

The team calibrated the true brightness of the eight slowly pulsating stars and cross-correlated them with their more distant blinking cousins to tighten the inaccuracies in their distance ladder. The researchers then compared the brightness of the Cepheids and supernovae in those galaxies with better confidence, so they could more accurately measure the stars' true brightness, and therefore calculate distances to hundreds of supernovae in far-flung galaxies with more precision.

Another advantage to this study is that the team used the same instrument, Hubble's Wide Field Camera 3, to calibrate the luminosities of both the nearby Cepheids and those in other galaxies, eliminating the systematic errors that are almost unavoidably introduced by comparing those measurements from different telescopes.

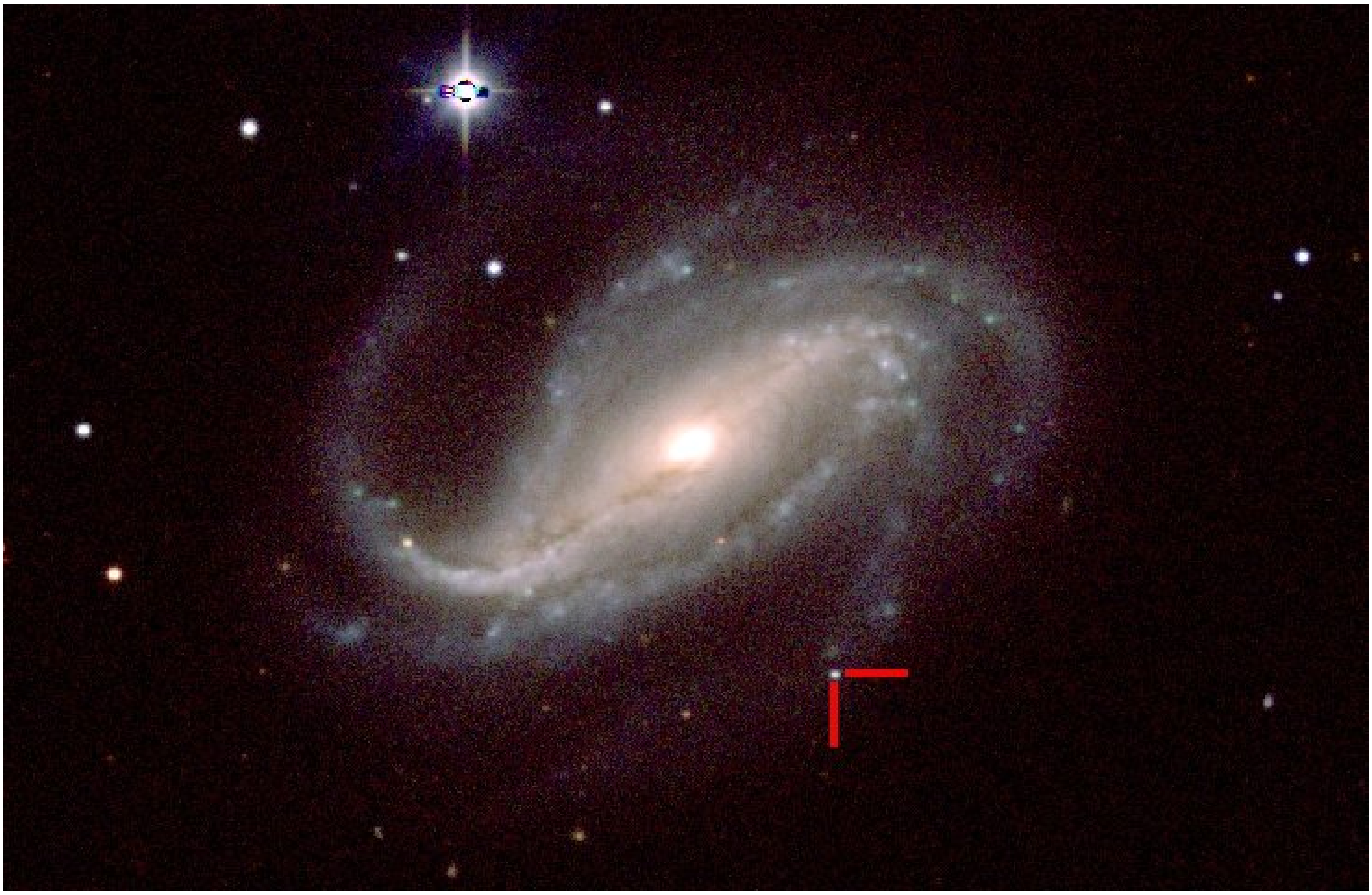
"Ordinarily, if every six months you try to measure the change in position of one star relative to another at these distances, you are limited by your ability to figure out exactly where the star is," Casertano explained. Using the new technique, Hubble slowly slews across a stellar target, and captures the image as a streak of light. "This method allows for repeated opportunities to measure the extremely tiny displacements due to parallax," Riess added. "You're measuring the separation between two stars, not just in one place on the camera, but over and over thousands of times, reducing the errors in measurement."

The team's goal is to further reduce the uncertainty by using data from Hubble and the European Space Agency's Gaia space observatory, which will measure the positions and distances of stars with unprecedented precision. "This precision is what it will take to diagnose the cause of this discrepancy," Casertano said.

The team's results have been accepted for publication by The Astrophysical Journal.

Source: NASA Return to Contents

## 3. Amateur Astronomer Captures Rare First Light from Massive Exploding Star



Thanks to lucky snapshots taken by an amateur astronomer in Argentina, scientists have obtained their first view of the initial burst of light from the explosion of a massive star.

During tests of a new camera, Víctor Buso captured images of a distant galaxy before and after the supernova's "shock breakout" - when a supersonic pressure wave from the exploding core of the star hits and heats gas at the star's surface to a very high temperature, causing it to emit light and rapidly brighten.

To date, no one has been able to capture the "first optical light" from a supernova, since stars explode seemingly at random in the sky, and the light from shock breakout is fleeting. The new data provide important clues to the physical structure of the star just before its catastrophic demise and to the nature of the explosion itself.

"Professional astronomers have long been searching for such an event," said UC Berkeley astronomer Alex Filippenko, who followed up the discovery with observations at the Lick and Keck observatories that proved critical to a detailed analysis of explosion, called SN 2016gkg. "Observations of stars in the first moments they begin exploding provide information that cannot be directly obtained in any other way."

"Buso's data are exceptional," he added. "This is an outstanding example of a partnership between amateur and professional astronomers."

The discovery and results of follow-up observations from around the world will be published in the Feb. 22 issue of the journal *Nature*.

On Sept. 20, 2016, Buso of Rosario, Argentina, was testing a new camera on his 16-inch telescope by taking a series of short-exposure photographs of the spiral galaxy NGC 613, which is about 80 million light years from Earth and located within the southern constellation Sculptor.

Luckily, he examined these images immediately and noticed a faint point of light quickly brightening near the end of a spiral arm that was not visible in his first set of images.

Astronomer Melina Bersten and her colleagues at the Instituto de Astrofísica de La Plata in Argentina soon learned of the serendipitous discovery and realized that Buso had caught a rare event, part of the first hour after light emerges from a massive exploding star. She estimated Buso's chances of such a discovery, his first supernova, at one in 10 million or perhaps even as low as one in 100 million.

"It's like winning the cosmic lottery," said Filippenko.

Bersten immediately contacted an international group of astronomers to help conduct additional frequent observations of SN 2016gkg over the next two months, revealing more about the type of star that exploded and the nature of the explosion.

Filippenko and his colleagues obtained a series of seven spectra, where the light is broken up into its component colors, as in a rainbow, with the Shane 3-meter telescope at the University of California's Lick Observatory near San Jose, California, and with the twin 10-meter telescopes of the W. M. Keck Observatory on Maunakea, Hawaii. This allowed the international team to determine that the explosion was a Type IIb supernova: the explosion of a massive star that had previously lost most of its hydrogen envelope, a species of exploding star first observationally identified by Filippenko in 1987.

Combining the data with theoretical models, the team estimated that the initial mass of the star was about 20 times the mass of our sun, though it lost most of its mass, probably to a companion star, and slimmed down to about 5 solar masses prior to exploding.

Filippenko's team continued to monitor the supernova's changing brightness over two months with other Lick telescopes: the 0.76-meter Katzman Automatic Imaging Telescope and the 1-meter Nickel telescope.

"The Lick spectra, obtained with just a 3-meter telescope, are of outstanding quality in part because of a recent major upgrade to the Kast spectrograph, made possible by the Heising-Simons Foundation as well as William and Marina Kast," Filippenko said.

Source: Phys.org

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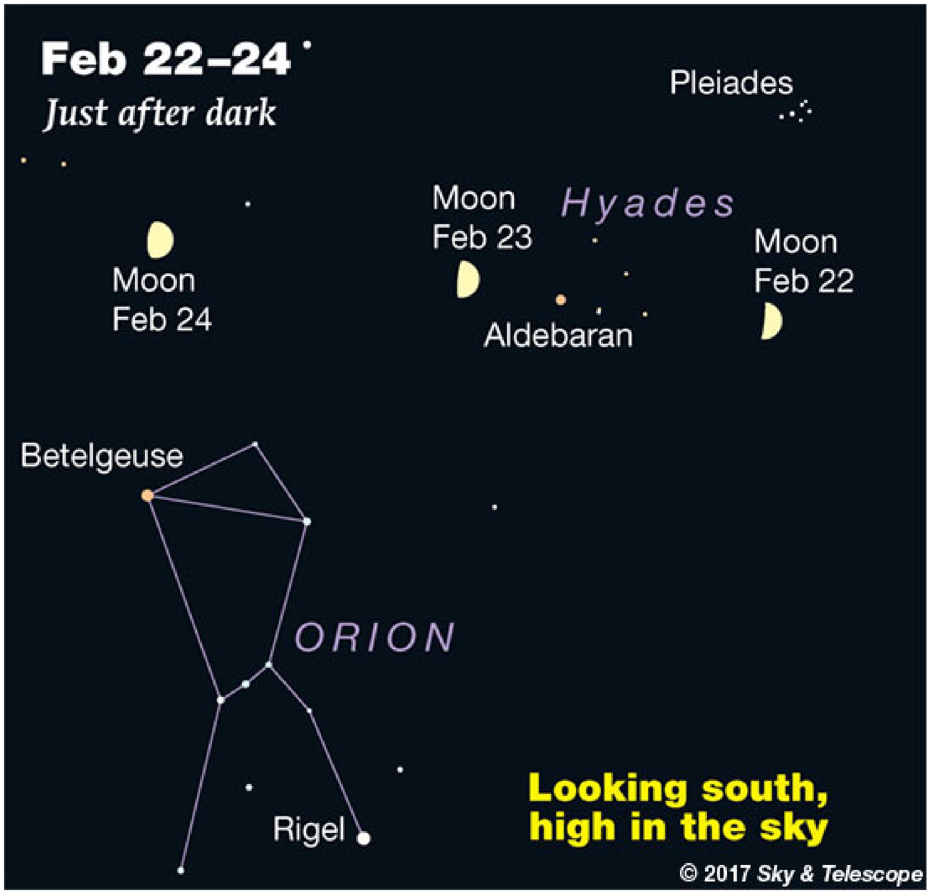
# The Night Sky




**Friday, February 23**
• First-quarter Moon (exact at 3:09 a.m. on this date EST). For North America this evening, the Moon shines left or upper left of Aldebaran, and farther upper right of Orion, as shown here.

The Moon occults Aldebaran in daylight or twilight for northern and western Europe, and in darkness for much of Russia; map and timetables.

**Saturday, February 24**
• The Moon shines over Orion after dark, as shown here.

• Algol should be at minimum brightness, magnitude 3.4 instead of its usual 2.1, for a couple hours centered on 10:05 p.m. EST (7:05 p.m. PST).

**Sunday, February 25**
• Have you ever seen Canopus, the second-brightest star after Sirius? In one of the many interesting coincidences that devoted skywatchers know about, Canopus lies almost due south of Sirius: by 36°. That's far enough south that it never appears above your horizon unless you're below latitude 37° N (southern Virginia, southern Missouri, central California). And there, you'll need a very flat southern horizon. Canopus crosses the south point on the horizon just 21 minutes before Sirius does.

*When* to look? Canopus is due south when Beta Canis Majoris — Mirzam the Announcer, the star about three finger-widths to the right of Sirius — is at *its* highest point due south (roughly 8:00 p.m. now, depending on how far east or west you are in your time zone). Look straight down from Mirzam then.

**Monday, February 26**
• The Big Dipper standing upright in the northeast means that Bootes is about to rise. The Dipper's handle famously arcs down and around toward Arcturus, Bootes's brightest star — and the arc crosses Bootes for most of the way. The whole constellation is above the east-northeast horizon by 9 or 10 p.m. now. Spring approaches.

**Tuesday, February 27**
• After dinnertime at this time of year, five carnivore constellations are rising upright in a row from the northeast to south. They're all seen in profile with their noses pointed up and their feet (if any) to the right. These are Ursa Major the Big Bear in the northeast with the Big Dipper as its brightest part, Leo the Lion in the east (with the bright Moon tonight!), dim Hydra the Sea Serpent in the southeast, Canis Minor the Little Dog higher in the south-southeast, and bright Canis Major the Big Dog in the south.

Source: Sky & Telescope Return to Contents

# ISS Sighting Opportunities

## For Denver:

| Date | Visible | Max Height | Appears | Disappears |
|---|---|---|---|---|
| Sat Feb 24, 6:14 AM | 2 min | 26° | 11° above S | 26° above SE |
| Sun Feb 25, 5:23 AM | 2 min | 13° | 10° above SSE | 13° above SE |
| Mon Feb 26, 6:05 AM | 5 min | 70° | 10° above SW | 22° above ENE |
| Tue Feb 27, 5:14 AM | 3 min | 33° | 14° above SSW | 29° above ESE |

Sighting information for other cities can be found at NASA's Satellite Sighting Information

# NASA-TV Highlights

**(all times Eastern Daylight Time)**

**2 p.m., Friday, February 23 -** Faster Weather Tracking on the Way with Upcoming Launch of GOES-S Weather Satellite," Live Social Event (all channels)

**2:30 p.m., 6 p.m., 10 p.m., Friday, February 23** - Replay of SpaceCast Weekly (all channels)

**4 p.m., 8 p.m., Friday, February 23 -** Replay of "Faster Weather Tracking on the Way with Upcoming Launch of GOES-S Weather Satellite," Live Social Event (all channels)

**1:30 p.m., Monday, February 26 -** Smithsonian National Air and Space Museum Presents: "What's New in Aerospace: How Geckos Helped JPL Make Some Really Cool Robotics" (NTV-1 (Public))

**2:30 p.m., Monday, February 26 -** ISS Expedition 54/55 Change of Command Ceremony (Misurkin hands over ISS command to Shkaplerov) (Starts at 2:40 p.m.) (all channels)

**1 p.m., Tuesday, February 27** - GOES-S Pre-Launch News Briefing from Kennedy Space Center (all channels)

**2 p.m., Tuesday, February 27** - Coverage of the Farewells and Hatch Closure for the Expedition 54 Crew on the ISS (Hatch closure scheduled at 2:50 p.m. ET) (Starts at 2:15 a.m.) (all channels)

**5:30 p.m., Tuesday, February 27 -** Coverage of the Undocking of the Expedition 54 Crew on Soyuz MS-06 from the ISS (Undocking scheduled at 6:08 p.m. EST) (starts at 5:45 p.m.) (all channels)

**8 p.m., Tuesday, February 27 -** Coverage of the Deorbit Burn and Landing of the Expedition 54 Crew on Soyuz MS-06 in Kazakhstan (Deorbit burn scheduled at 8:38 p.m. ET, landing near Dzhezkazgan, Kazakhstan scheduled at 9:31 p.m. ET) (all channels)

Watch NASA TV on the Net by going to the NASA website. Return to Contents

# Space Calendar

- Feb 23 - Moon Occults Aldebaran
- Feb 23 - Asteroid 48 Doris Occults HIP 14764 (6.0 Magnitude Star)
- Feb 23 - Atira Asteroid 2013 TQ5 Closest Approach To Earth (0.374 AU)
- Feb 23 - Asteroid 12104 Chesley Closest Approach To Earth (2.067 AU)
- Feb 23 - Asteroid 160512 Franck-Hertz Closest Approach To Earth (2.376 AU)
- Feb 23 - Standing Up For Science Workshop, Belfast, Ireland
- Feb 24 - HOT [Feb 17] 50th Anniversary (1968), Jocelyn Bell's & Antony Hewish's Discovery of Pulsars Announced
- Feb 24 - Comet 146P/Shoemaker-LINEAR At Opposition (3.969 AU)
- Feb 24 - Comet C/2014 B1 (Schwartz) Closest Approach To Earth (8.613 AU)
- Feb 24 - Aten Asteroid 2017 DR109 Near-Earth Flyby (0.009 AU)
- Feb 24 - NEW [Feb 17] Apollo Asteroid 2018 CE14 Near-Earth Flyby (0.013 AU)
- Feb 24 - Asteroid 1855 Korolev Closest Approach To Earth (1.087 AU)
- Feb 24 - Aten Asteroid 99942 Apophis Closest Approach To Earth (1.552 AU)
- Feb 24 - Asteroid 10195 Nebraska Closest Approach To Earth (2.379 AU)
- Feb 25 - IGS-Optical 6 H-2A Launch
- Feb 25 - UPDATED [Feb 21] Hispasat 30W-6 Falcon 9 Launch
- Feb 25 - Mercury Passes 0.5 Degrees From Neptune
- Feb 25 - Comet 103P/Hartley Closest Approach To Earth (2.438 AU)
- Feb 25 - Comet P/2018 C1 (Lemmon-Read) Perihelion (2.595 AU)
- Feb 25 - Comet C/2014 R3 (PANSTARRS) Closest Approach To Earth (7.258 AU)
- Feb 25 - Comet C/2014 B1 (Schwartz) At Opposition (8.614 AU)
- Feb 25 - Asteroid 8749 Beatles Closest Approach To Earth (1.089 AU)
- Feb 25 - Asteroid 171183 Haleakala Closest Approach To Earth (2.042 AU)
- Feb 26 - Comet C/2017 S6 (Catalina) Perihelion (1.543 AU)
- Feb 26 - NEW [Feb 20] Aten Asteroid 2018 DA Near-Earth Flyby (0.028 AU)
- Feb 26 - Apollo Asteroid 2016 FU12 Near-Earth Flyby (0.034 AU)
- Feb 26 - Apollo Asteroid 2004 CK39 Near-Earth Flyby (0.086 AU)
- Feb 26 - Apollo Asteroid 2017 DF38 Near-Earth Flyby (0.098 AU)
- Feb 26 - Amor Asteroid 4487 Pocahontas Closest Approach To Earth (1.151 AU)
- Feb 26 - Susan Helms' 60th Birthday (1958)
- Feb 27 - HOT [Feb 20] Soyuz MS-6 Return To Earth (International Space Station)
- Feb 27 - Comet 321P/SOHO At Opposition (3.810 AU)
- Feb 27 - Comet P/2017 W3 (Gibbs) Perihelion (3.833 AU)
- Feb 27 - Asteroid 4 Vesta Occults TYC 6237-00876-1 (11.2 Magnitude Star)
- Feb 27 - NEW [Feb 20] Apollo Asteroid 2018 CU14 Near-Earth Flyby (0.014 AU)
- Feb 27 - Apollo Asteroid 2014 EY24 Near-Earth Flyby (0.038 AU)
- Feb 27 - Asteroid 1831 Nicholson Closest Approach To Earth (1.289 AU)
- Feb 27 - Asteroid 11908 Nicaragua Closest Approach To Earth (1.942 AU)

Source: JPL Space Calendar

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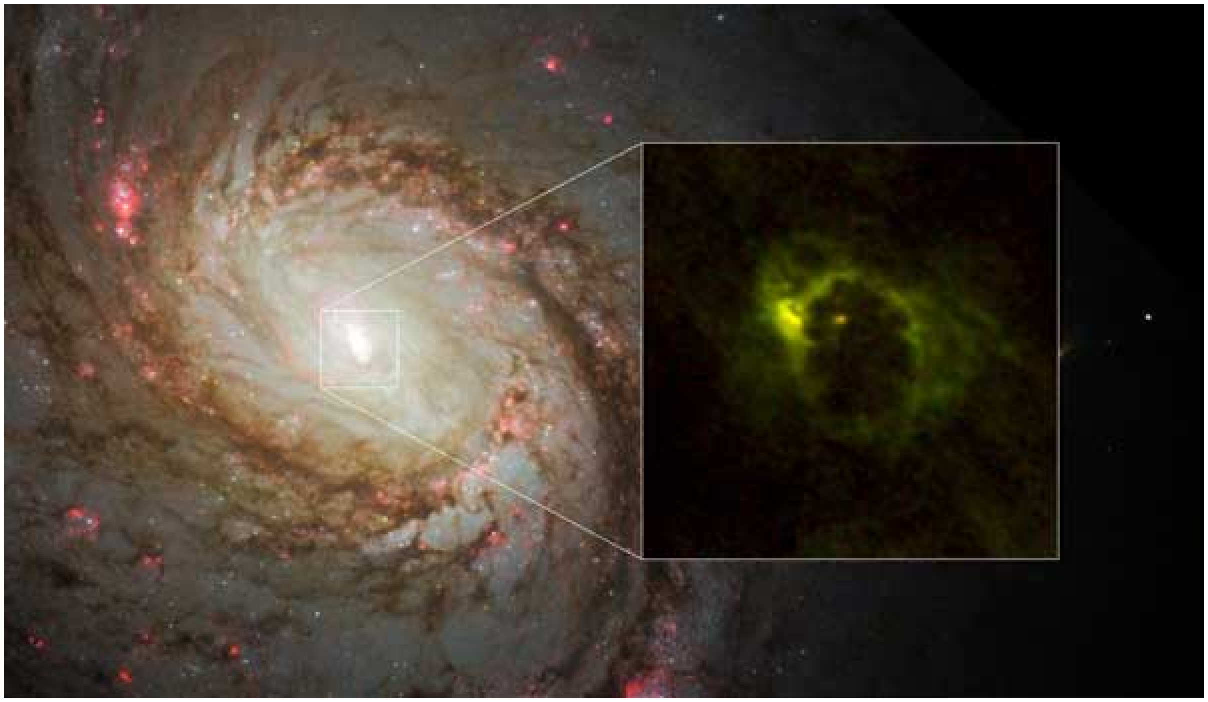
# Food for Thought

## Astronomers Watch Donut Rotate Around Supermassive Black Hole



***Astronomers have detected a torus rotating around the supermassive black hole at the center of spiral galaxy Messier 77, collecting observations that may shed light on why these weird structures exist.***

From car tires to chocolate-frosted donuts to infinity scarves, the torus is a relatively common shape in modern life. But the same can't be said for nature, where globular shapes and thin disks are far more typical.

That's why the torus is one of the more striking features of *active galactic nuclei*(AGN). In AGN supermassive black holes are gorging on gas, which heats up until it's radiating more brightly than the entire host galaxy. But decades of indirect data show that these luminous behemoths often hide behind a fat, dusty torus. To explain observations, the torus must cover half of the AGN's sky, which means it must be roughly as fat as it is tall — somewhere around 3 light-years for both dimensions.

Such a structure ought to collapse into a disk within 100,000 years. Instead, they apparently stick around for hundreds of millions of years — and astronomers still don't know why.

That's beginning to change with observations of Messier 77 (M77, aka NGC 1068), a black hole 10 million times the mass of the Sun that's partially hidden by its encircling torus. The Atacama Large Millimeter/submillimeter Array (ALMA), high in the Atacama Desert in Chile, can image the torus itself, capturing the rotating, outflowing, and turbulent motions of its gas.

In 2016 Santiago García-Burillo (National Astronomical Observatory of Madrid) and Jack Gallimore (Bucknell University) led teams reporting ALMA observations of M77 that peer into the galaxy's core. Both teams used carbon monoxide molecules to trace vastly more abundant (but more difficult to observe) molecular hydrogen gas. While Garcia-Burillo's team captured turbulence in the torus, Gallimore's group caught an outflow, presumably coming from the accretion disk, that's blowing into (and puffing up) the torus.

Now, Masatoshi Imanishi (National Astronomical Observatory of Japan) and colleagues have imaged M77's torus in even greater detail, with images twice as sharp as previous ones. The results appear in *Astrophysical Journal Letters*.

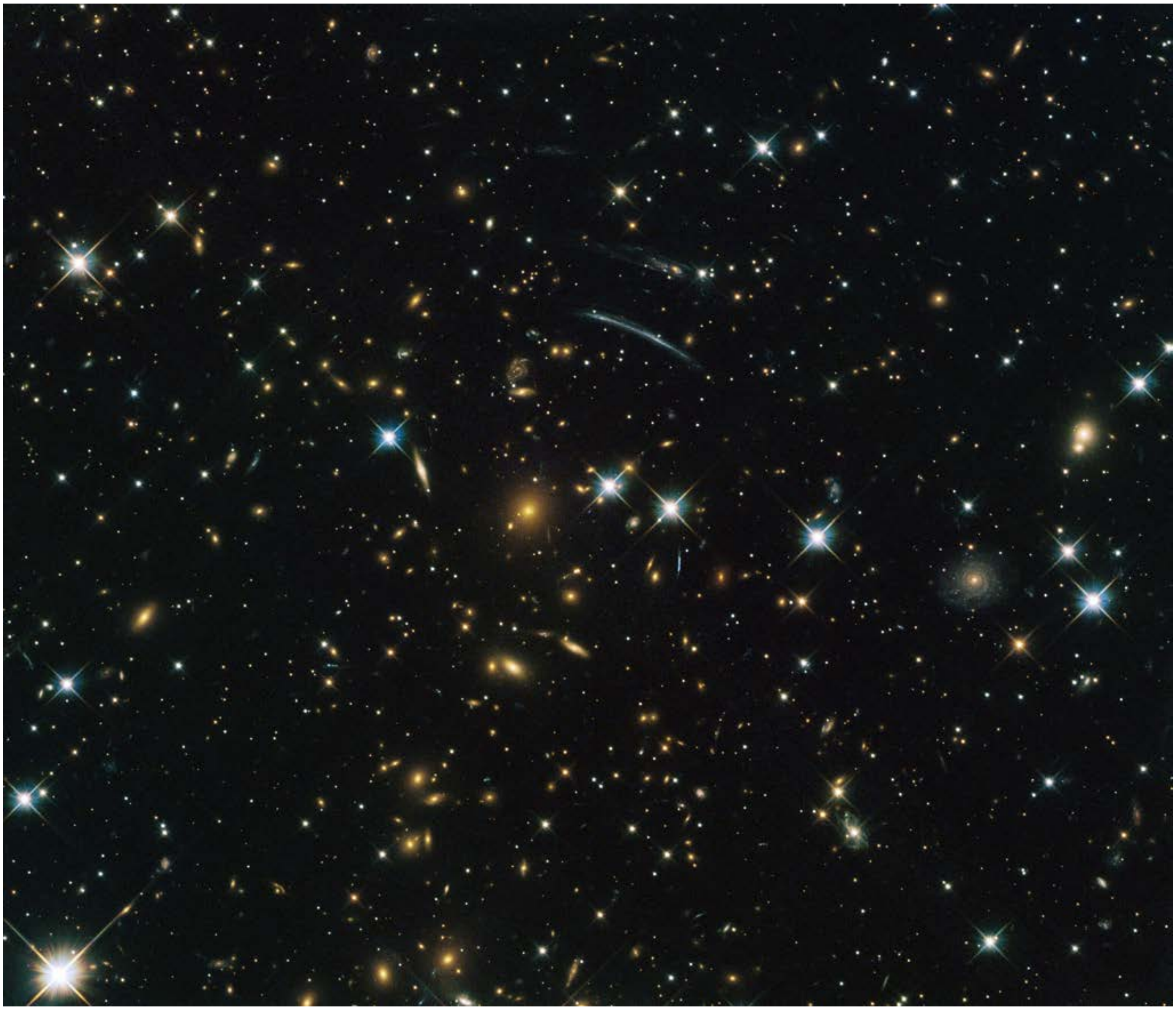
The team measured hydrogen cyanide — while it's a poisonous acid on Earth, it serves as a tracer of dense hydrogen gas in space. Because their observations follow denser gas, they're able to capture the rotational motions of the torus. The 20 light-year-wide donut orbits the supermassive black hole at roughly 10 kilometers per second (20,000 mph).

However, further analysis indicates that there's a lot more to the torus than rotation — their observations are consistent with the previous results showing other motions (turbulence and outflows) that sustain the torus.

"ALMA is doing a fantastic job exposing the secrets of NGC 1068, and the observations are only getting better," Gallimore says.

Source: Sky & Telescope Return to Contents

## Space Image of the Week



**A Window Into The Cosmic Past**

This image from the NASA/ESA Hubble Space Telescope shows the galaxy cluster PLCK G004.5-19.5. It was discovered by the ESA Planck satellite through the Sunyaev-Zel'dovich effect -- the distortion of the cosmic microwave background radiation in the direction of the galaxy cluster by high-energy electrons in the intracluster gas. The large galaxy at the center is the brightest galaxy in the cluster, and above it a thin, curved gravitational lens arc is visible. This arc is caused by the gravitational forces of the cluster bending the path of light from stars and galaxies behind it, in a similar way to how a glass lens bends light.

Several stars are visible in front of the cluster -- recognizable by their diffraction spikes -- but aside from these, all other visible objects are distant galaxies. Their light has become redshifted by the expansion of space, making them appear redder than they actually are. By measuring the amount of redshift, we know that it took more than 5 billion years for the light from this galaxy cluster to reach us. The light of the galaxies in the background had to travel even longer than that, making this image an extremely old window into the far reaches of the universe.

Source: SpaceRef.com Return to Contents